**Chapter 23 Section 4** **Minor Members of the Solar System**

**Key Concepts**

Where are most asteroids located?

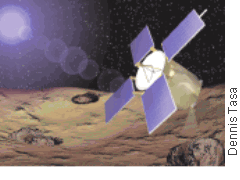
What is the structure of a comet?

What is the origin of most meteoroids?

**Vocabulary**

* meteoroid
* meteor
* meteorite
* asteroid
* comet
* coma

In February 2001 an American spacecraft, *NEAR Shoemaker,* finished its mission in spectacular fashion—it became the first visitor to an asteroid. This historic accomplishment was not part of *NEAR Shoemaker’s* original goal, which was to orbit the asteroid, taking images and gathering data about these objects in space. With this mission accomplished, however, NASA engineers wanted to see if they could actually land a spacecraft on an asteroid. The data they would gather would be priceless. As an added benefit, NASA would gain valuable experience that might help in the future to deflect an asteroid on a collision course with Earth.

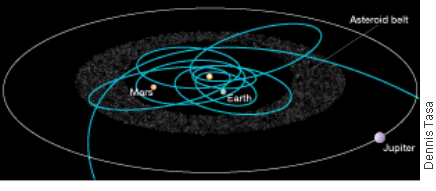
Although it was not designed for landing, *NEAR Shoemaker—*shown in Figure 20—successfully touched down on the asteroid, Eros. It generated information that has planetary geologists both intrigued and perplexed. The spacecraft drifted toward the surface of Eros at the rate of 6 kilometers per hour. The images obtained revealed a barren, rocky surface composed of particles ranging in size from fine dust to boulders up to 8 meters across. Researchers unexpectedly discovered that fine debris is concentrated in the low areas that form flat deposits resembling ponds. Surrounding the low areas, the landscape is marked by an abundance of large boulders.

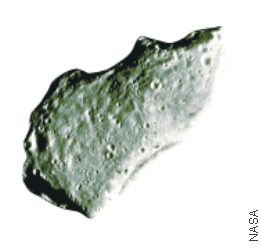
**Figure 20** *This artist’s rendition shows NEAR Shoemaker touching down on the asteroid Eros.*

Seismic shaking is one of several hypotheses being considered as an explanation for the boulder-laden topography. This shaking would move the boulders upward. The larger materials rise to the top while the smaller materials settle to the bottom, which is similar to what happens when a can of mixed nuts is shaken.

**Asteroids: Microplanets**

What exactly is an asteroid? **Asteroids** are small rocky bodies that have been likened to “flying mountains.” The largest, Ceres, is about 1000 kilometers in diameter, but most are only about 1 kilometer across. The smallest asteroids are assumed to be no larger than grains of sand. **Most asteroids lie between the orbits of Mars and Jupiter. They have orbital periods of three to six years.** Some asteroids have very eccentric orbits and travel very near the sun, and a few larger ones regularly pass close to Earth and the moon as shown by the diagram in Figure 21. Many of the most recent impact craters on the moon and Earth were probably caused by collisions with asteroids. Inevitably, future Earth- asteroid collisions will occur, as discussed in this chapter’s feature on page 665.

**Figure 21** *The orbits of most asteroids lie between Mars and Jupiter. Also shown are the orbits of a few near-Earth asteroids. Perhaps a thousand or more asteroids pass close to Earth. Luckily, only a few dozen are thought to be larger than 1 kilometer in diameter.*

Many asteroids have irregular shapes, as shown in Figure 22. Because of this, planetary geologists first speculated that they might be fragments of a broken planet that once orbited between Mars and Jupiter. However, the total mass of the asteroids is estimated to be only 1/1000 that of Earth, which itself is not a large planet. What happened to the remainder of the original planet? Others have hypothesized that several larger bodies once coexisted in close proximity, and their collisions produced numerous smaller ones. The existence of several families of asteroids has been used to support this explanation. However, no conclusive evidence has been found for either hypothesis.

**Figure 22** *Asteroid 951, also called Gaspra, is probably the fragment of a larger body that was torn apart by a collision.*

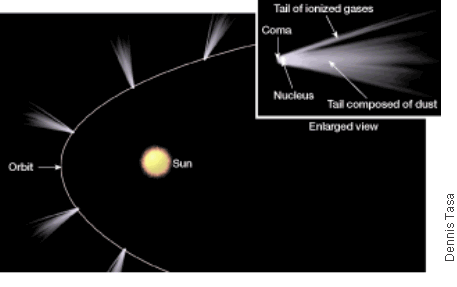
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| **Reading Checkpoint** |
| (a)What is an asteroid? |

**Comets**

Comets are among the most interesting and unpredictable bodies in the solar system. **Comets** are pieces of rocky and metallic materials held together by frozen gases, such as water, ammonia, methane, carbon dioxide, and carbon monoxide. Many comets travel in very elongated orbits that carry them far beyond Pluto. These comets take hundreds of thousands of years to complete a single orbit around the sun. However, a few have orbital periods of less than 200 years and make regular encounters with the inner solar system.

**Coma**

When first observed, a comet appears very small. But as it approaches the sun, solar energy begins to vaporize the frozen gases. This produces a glowing head called the **coma**, shown in Figure 23. **A small glowing nucleus with a diameter of only a few kilometers can sometimes be detected within a coma. As comets approach the sun, some, but not all, develop a tail that extends for millions of kilometers.**

**Figure 23** *A comet’s tail always points* ***away*** *from the sun.*

The fact that the tail of a comet points away from the sun in a slightly curved manner led early astronomers to propose that the sun has a repulsive force that pushes the particles of the coma away, thus forming the tail. Today, two solar forces are known to contribute to this formation. One, radiation pressure, pushes dust particles away from the coma. The second, known as solar wind, is responsible for moving the ionized gases, particularly carbon monoxide. You’ll learn more about solar wind in the next chapter. Sometimes a single tail composed of both dust and ionized gases is produced, but often two tails are observed.

As a comet moves away from the sun, the gases forming the coma recondense, the tail disappears, and the comet returns to cold storage. Material that was blown from the coma to form the tail is lost from the comet forever. Therefore it is believed that most comets cannot survive more than a few hundred close orbits of the sun. Once all the gases are expelled, the remaining material—a swarm of tiny metallic and stony particles—continues the orbit without a coma or a tail.

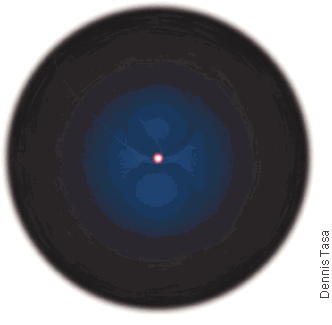
**Kuiper Belt**

Comets apparently originate in two regions of the outer solar system. Those with short orbital periods are thought to orbit beyond Neptune in a region called the Kuiper belt. Like the asteroids in the inner solar system, most Kuiper belt comets move in nearly circular orbits that lie roughly in the same plane as the planets. A chance collision between two Kuiper belt comets, or the gravitational influence of one of the Jovian planets, may occasionally alter the orbit of a comet enough to send it to the inner solar system, and into our view.

**Oort Cloud**

Unlike Kuiper belt comets, comets with long orbital periods aren’t confined to the plane of the solar system. These comets appear to be distributed in all directions from the sun, forming a spherical shell around the solar system called the Oort cloud. See Figure 24. Millions of comets are believed to orbit the sun at distances greater than 100,000 times the Earth-sun distance. The gravitational effect of another object in space is thought to send an occasional Oort cloud comet into a highly eccentric orbit that carries it toward the sun. However, only a tiny portion of the Oort cloud comets pass into the inner solar system.

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| **Reading Checkpoint** |
| (a) In which direction does the tail of a comet point? |



**Figure 24** *The Oort cloud is a sphere of comets surrounding the sun and planets.*

**Halley’s Comet**

The most famous short-period comet is Halley’s comet. Its orbital period averages 76 years, and every one of its 29 appearances since 240 **b.c.** has been recorded by Chinese astronomers. When seen in 1910, Halley’s comet had developed a tail nearly 1.6 million kilometers long and was visible during the daylight hours.

In 1986, the European probe *Giotto* approached to within 600 kilometers of the nucleus of Halley’s comet and obtained the first images of this elusive structure. We now know that the nucleus is potato-shaped, 16 kilometers by 8 kilometers. The surface is irregular and full of craterlike pits. Gases and dust that vaporize from the nucleus to form the coma and tail appear to gush from its surface as bright jets or streams. Only about 10 percent of the comet’s total surface was emitting these jets at the time of the rendezvous. The remaining surface area of the comet appeared to be covered with a dark layer that may consist of organic material.

**Meteoroids**

Nearly everyone has seen a “shooting star.” This streak of light occurs when a meteoroid enters Earth’s atmosphere. A **meteoroid** is a small solid particle that travels through space. **Most meteoroids originate from any one of the following three sources:**

**(1) Interplanetary debris that was not gravitationally swept up by the planets**

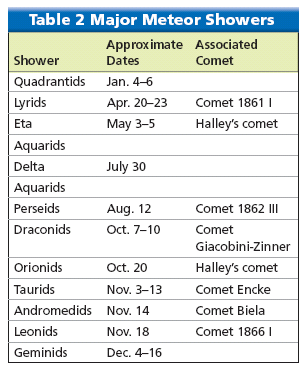
**during the formation of the solar system**

**(2) Material from the asteroid belt**

**(3) The solid remains of comets that once traveled near Earth’s orbit.**

A few meteoroids are believed to be fragments of the moon, or possibly Mars, that were ejected when an asteroid impacted these bodies.

Some meteoroids are as large as asteroids. Most, however, are the size of sand grains. Consequently, they vaporize before reaching Earth’s surface. Those that do enter Earth’s atmosphere and burn up are called **meteors**. The light that we see is caused by friction between the particle and the air, which produces heat.

Occasionally, meteor sightings can reach 60 or more per hour. These displays, called meteor showers, result when Earth encounters a swarm of meteoroids traveling in the same direction and at nearly the same speed as Earth. As shown in Table 2, the close association of these swarms to the orbits of some comets strongly suggests that they are material lost by these comets. The notable Perseid meteor shower occurs each year around August 12 and is believed to be the remains of the Comet 1862 III.

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| **Reading Checkpoint** |
| (a) What is a meteor shower? |

A meteoroid that actually reaches Earth’s surface is called a **meteorite**. A few very large meteorites have blasted out craters on Earth’s surface, similar to those on the moon. The most famous is Meteor Crater in Arizona. (See pages 642–643.) This huge cavity is about 1.2 kilometers across, 170 meters deep, and has an upturned rim that rises 50 meters above the surrounding countryside. Over 30 tons of iron fragments have been found in the immediate area, but attempts to locate the main body have been unsuccessful. Based on erosion, the impact likely occurred within the last 20,000 years.

Prior to moon rocks brought back by astronauts, meteorites such as the one in Figure 25 were the only extraterrestrial materials that could be directly examined. Meteorite dating indicates that our solar system’s age exceeds 4.5 billion years. This “old age” has been confirmed by data from lunar samples.

**Figure 25** *This meteorite, made up of mostly iron, was found in the desert sands.*

**Chapter 21 SECTION 4 Minor Members of the Solar System Assessment**

**Reviewing Concepts**

(1) Where are most asteroids located?

(2)Describe the structure of a comet.

(3)Where do short-period comets come from? What about long-period comets?

(4) Meteoroids originate from what three sources?

**Critical Thinking**

(5) **Comparing And Contrasting** Compare and contrast a meteoroid, meteor, and meteorite.

(6) **Predicting** What do you think would happen if Earth passed through the tail of a comet?

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